Proceedings of the APAN – Research Workshop 2019
ISBN 978-4-9905448-9-8

A journey from Cure to Care- Wellness management for healthy lifestyle: Diabetes management a case study

[1,2]Hafiz Syed Muhammad Bilal, [3]Asad Masood Khattak, [1]Sungyoung Lee

Abstract— **Smart ubiquitous computing has a vital role to avoid and indicate the preventable lifestyle-based chronic diseases. It is focusing to adopt a healthy lifestyle by converging science and technology in this digital world for improving health and quality of life. From the last decade, the development of wellness applications has supported personalization and self-quantification. These applications facilitate the users through activity tracking and monitoring, based on the raw sensory data to adopt healthy behavior. The challenge of behavior change is not only to indicate the issues but also provides step-by-step coaching and guidance at real time. The realization of behavior change theories through digital technology has revolutionized the lifestyle change in a systematic and measurable manner. We have proposed a methodology to understand the behavior for generating just-in-time intervention for adopting a healthy lifestyle. Wellness platform based behavior analysis is performed using unbiased life-log and questionnaire for qualitative assessment of behavior. Behavior stage wise intervention is provided to adapt behavior for enhancing the quality of life and boost the socio-economic conditions. Personalized education is provided to understand the importance of healthy behavior and motivate the users, whereas just-in-time context-based recommendations have supported the stage-wise adaptation of unhealthy behavior. These capabilities require status evaluation of the activities and an efficient way to portray the comprehensive index of lifestyle habits. The real focus is to correlate the primarily linked habits in appropriate proportion through healthy behavior index (HBI) for personalized wellness support services. The healthy behavior index and behavior change theories through smart technologies have enhanced the functionality of wellness management system and support behavior status sketching to adopt healthy activities for the betterment of long life. The results depict that education and recommendation as per person stage are more responsive and attractive to retain the attention of the customers.**

***Index Terms*— Just-in-time intervention, lifestyle habits, recommendations, wellness services, ubiquitous computing.**

I. INTRODUCTION

BEHAVIOR related to lifestyle requires continuous monitoring and intervention to adapt healthy one. The unhealthy lifestyle cause lot of health complications as well as degrade the quality of life in terms of social and economic prospects.

The personal awareness about lifestyle status has been revolutionized from last decade. It is mainly due to the advancement in technology of smart gadgets and lot of health applications. The wellness application collect variety of data through built-in sensors like gyroscope, accelerometer, proximity, magnetometer and light sensors. The obtained data in wellness application is used to determine the target in the form of number of steps, weight loss, and women's health during pregnancy and calories consumption. Now, it is believed that future of health domain lies in big data [1].

The traditional way of behavior adaptation is changing from long interactions of physician to just-in-time interventions. Which overcome the tedious task, which depends on human memory and some biasness. In the wellness management, it is very necessary to understand what are unhealthy behaviors and the consequences of those behaviors.

A. Unhealthy Lifestyle Behavior

Healthy lifestyle not only adding years to life but also enhance the economic and social aspects of life and community. People with healthy lifestyle enjoy more with good health and depend less on care givers and support providers. The lifestyle depends on physical activity, balanced

This research was supported by the Ministry of Science and ICT (MSIT), Korea, under the Information Technology Research Center (ITRC) support programme (IITP-2017-0-01629) supervised by the Institute of Information & Communications Technology Planning & Evaluation (IITP), this work was supported by an IITP grant funded by the Korean government (MSIT) (no.2017-0-00655) and this research work was supported by Zayed University Research Incentives Fund (R18052).

[1]Department of Computer Science and Engineering, Kyung Hee University, Seocheon-dong, Giheung-gu, Yongin-si, Gyeonggi-do, 446-701, Republic of Korea, (e-mail: {sylee,bilalrizvi}@oslab.khu.ac.kr).

[2]National University of Sciences and Technology, Islamabad, 44000, Pakistan (e-mail: bilal.ali@seecs.edu.pk).

[3]College of Technological Innovation, Zayed University, Abu Dhabi, UAE(e-mail: asad.khattak@zu.ac.ae)

diet, alcohol consumption, and smoking as discussed in Table I and are all adaptable behaviors of lifestyle.

The sedentary lifestyle is defined as the waking time spend in activities whose MET value is less than 3. The interrupts at regular intervals in sedentary behavior improve the person metabolic process [2]. So indication of prolonged physical inactivity behavior helps to change the lifestyle for long healthy life. Similarly, balanced diet consumption provides foundation for healthy life and reduces the probability of chronic diseases development. It is a persuasive health agent and unhealthy diet pattern is one of the causes of chronic diseases and premature death [3]. The balanced diet is a combination of multiple nutrients in different proportions which are necessary for the nurturing of vital organs, whereas excess of some nutrient is dangerous also.

Smoking and Drinking are two most negatively criticized lifestyle habits. Abuse of alcohol and smoking lay foundation of multiple and critical health issues that range from mild to life-threatening. The only exception is moderate consumption of alcohol [4]. The knowledge about the complications of alcohol consumption and smoking on the body can motivate to reduces or avoid abuse. Innovative interventions and wellness systems are needed to reach addicted person effectively and efficiently.

TABLE I
LIFESTYLE BASED BEHAVIORS

Lifestyle Behavior	Categories	Definition
Diet	Poor	Irregular, Imbalanced, High Sugar, High Salt
	Fair	Partial Regular, Partial Balanced
	Adequate	Regular, Balanced 5 groups, Low salt, Low sugar
Physical Activity	Sedentary	Action Activities' MET between 0-1.5 /day
	Moderately Active	Activities' MET between 1.5-3.0 /day
	Active	Activities' MET >3.0 /day
Smoking	Heavy Smoker	More than 1 Pack/day
	Light Smoker	Less than 1 Pack/ day
	Non Smoker	Occasional /Never Smoker
Alcohol	Heavy Drinker	10 to 24 (men), 6 to 17(women) drinks/week
	Moderate Drinker	5 to 9 (men), 3 to 5(women) drinks/week
	No / Light Drinker	0 to 4 (men), 0 to 25(women) drinks/week

MET = Metabolic equivalent, Activities'MET= physical activities with MET value; Regular = 3 times a day with at least 5 to 6 hours gap, Balanced 5 group= whole grains, dairy, poultry fruits and vegetables, High Salt= greater than 2.5 grams per day, High Sugar= greater than 40 grams per day.

B. Lifestyle Based Chronic Diseases

Lifestyle pattern such as regular exercise, non-sedentary activities, balanced diet, not smoking and controlled alcohol consumption, prevents and manages lifestyle-related non-communicable diseases [5] as shown in Table II. These diseases are heart disease, hypertension, stroke, muscles problem, bone disorder, cancer, obstructive lung disease, obesity, diabetes and chronic back pain. The indication of lifestyle pattern related to the non-communicable diseases is very important to have healthy and long quality life.

TABLE II
LIFESTYLE BEHAVIOR IMPACT ON DISEASES

Lifestyle Factors	Diabetes	CVD	Obesity	Metabolic Syndrome	Cancer
Regular Physical Exercise	+ve	+ve	+ve	+ve	+ve
Quite Smoking	+ve	+ve	-ve		+ve
Maintain Healthy BMI	+ve	+ve	+ve	+ve	+ve
Intake Whole Grain	+ve	+ve	+ve	+ve	
Reduce Sugar	+ve	+ve	+ve	+ve	
Reduce Salt	+ve				
Eat Fruits & Vegetables		+ve	+ve		
Recommended Calories	+ve	+ve	+ve	+ve	
Recommended Fats (Unsaturated)	+ve	+ve		+ve	

Lifestyle factors are the very basic and fundamental aspects of daily routine physical and diet portion.

Diseases are Diabetes = Diabetese type 2, CVD= Cardiovascular Disease, Obesity= BMI greater than 30; BMI=Body Mass Index, Regular Physical Activity= Moderate to vigorous activity for 25-30 mins per day, Recommended Calories =2000-2500 Cal per day; +ve= positive impact on disease, -ve=bad impact on disease.

C. Wellness Management Applications

The concern of the health care and wellness applications is to manage and analyze the log of individual's activities to identify healthy and unhealthy behavior [6]. The trend of reactive approach towards disease management has been shifted to disease avoidance through personalized behavior pattern identification. The recognized activities' patterns proactively support to diagnose the cause of any undesired health issue. Multiple ubiquitous applications are available, i.e. RunKeeper, Noom Coach ,GoogleFit, and etc. Generally, these applications quantify user activities through step counts, calories consumption, and support visualization of user activities status.

D. Behavior Change Theories

There are multiple behavior change theories which emphasis on the step wise permanent change of behavior. The focus of wellness management organizations to enhance quality of life. The behavior change is governed by behavior change theories which focus attitude, abilities, environment, and triggers of an individual to change lifestyle [7]. Generally, these theories consist of theory of planned behavior, social cognitive theory, Fogg behavior model, transtheoretical model, theory of reasoned action, and etc as discussed in Table III. These theories have different prospects and focuses to understand the behavior and change it accordingly.

TABLE IV
BEHAVIOR CHANGE THEORIES

Categories	Definition
Theory of planned Behavior	The theory of planned behavior determines an individual's intention of behavior through attitude and subjective norms
Theory of reasoned action	Theory of reasoned action explains that individuals consider the consequences before performing a particular behavior
Fogg behavior model	The Fogg Behavior Model focuses on three basic ingredients of behavior occurs: 1) motivation, 2) ability, and 3) trigger.
Social cognitive theory	Social cognitive theory deals with personal factors, individual ability, and environmental factors.
Transtheoretical model	The Transtheoretical model emphasizes multiple stages of behavior change: 1) precontemplation, 2) contemplation, 3) preparation, 4) action, and 5) maintenance

II. PROPOSED METHODOLOGY FOR BEHAVIOR CHANGE

Wellness literature highlights that unhealthy behavior consists of physical inactivity, higher alcohol intake, smoking, and imbalanced diet. The unhealthy lifestyle has an associated increased risk of lifestyle based diseases like hypertension, cardiovascular disease, obesity, cancer, and premature mortality [8]. The proactive approach to avoid fetal diseases is to improve lifestyle behavior.

The behavior adaptation is a continuous process which requires indication and guidance of unhealthy behaviors. The smart computing, inter of things, body sensors, and life-logging have revolutionized wellness awareness domain [9]. Which supports the customers to observe the activities' status to meet the lifestyle goal. The user-centric data, logs the activities to indicate the daily milestones of step counts, sleep hours, water intake, calories burned, and weight management [10]. However, user life-log strengthens the concept of just-in-time personalized intervention to support the adaptation of healthy behavior.

A. *Transtheoretical Model based Philosophy*

The Transtheoretical Model (TTM) is the commonly used model for health-related behavior change [11], [13]. The model divided the users into five stages with respect to understanding and actions to perform the change in behavior. The stages are mapped to registration, education, recommendation, and evaluation with the range of time limit as shown in Fig. 1. The detail of these stages are discussed according to the user condition as follows:

1) Precontemplation (Not Ready)

The user at this stage, have no idea of the unhealthy behavior and their impact on the health. Because of this lack of knowledge, usually user has no intention to perform any change in behavior in next six months.

2) Contemplation (Getting Ready)

The users at this stage have idea about the complications of the unhealthy behavior and desire to adapt in near future. The decision between cost and benefits usually cause confusion and delay in behavioral change.

3) Preparation (Ready for action)

The user at this stage are set to perform healthy behavior directly. They have accepted the benefits of the behavioral change and ready for action.

4) Action

The user has adopted healthy lifestyle behavior and followed appropriate one form recent past. The log of actions can be observed from the recommendations and recorded actions. The strategy for observing healthy actions is the scientific quantification of the behavior i.e. amount of alcohol consumed in a week.

5) Maintenance

The observation of individual routine to verify the status of the adopted behavior and avoiding the relapse. The confidence level increases gradually as individual gains trust that changed routine is exercised continuously. The permanent habitual change process requires lot of determination and patience.

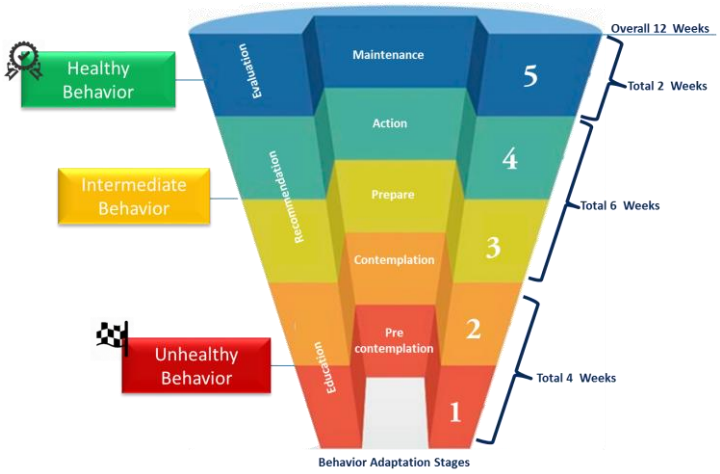

Figure 1 Proposed philosophy for behavior adaptation

B. *Wellness Management Platform-Mining Minds*

Mining Minds (MM) is an open source wellness platform which supports to get data from multiple sensors, analyzed it and generate recommendations [10], [12]. The acquired data is related to recognized activities, emotions, and location which is persisted into intermediate database and big data for instant recommendations and analytics as shown in Fig. 2. It consists of multiple layers to curate data, information, knowledge, and service to support user by providing real time wellness recommendations.

The Supporting Layer SL interacts with users and provides analytics. On the basis of the access level permission, graphical view of lifestyle habits, activity status, and health statistics are provided to expert and users. The Service Curation Layer (SCL) orchestrates the personalized recommendation based on demographic, context, emotion, preferences and physiological factors. The recommendations are adaptable based on the lifestyle status of the user. The orchestrator in SCL manages the pull and push based recommendations' communication for just-in-time interventions as well as circadian rhythm based diet plan. The SCL builds and refines the recommendations with the help of

high level context, SNS data, and the guidelines provided by the expert to handle the respective unhealthy habits. It also consider the amount of calories required and calories consumed based on MET and BMI values.

The Knowledge Curation Layer (KCL) supports expert to transform their experiences and wellness knowledge in to rules through an authoring environment [14]. These rules guide about the wellness context based situation awareness and identification in the life-log. Moreover, these rules support to suggest the recommendation in a specific unhealthy situation to adapt healthy lifestyle. The suggestions are the action plan for the targeted risky and unhealthy lifestyle habit, so instead of providing general recommendations we have adaptive recommendations on the basis of only harmful habits.

The Information Curation Layer (ICL) identifies user's activities and context from multimodal sensory data managed in hierarchical models. It employees emotion, location and multiple activity recognizers respectively. These recognizers generate the low level context and the fusioning of these context build high level context which are curated in Data Curation Layer (DCL). The DCL manages the data in raw as well as processed format through data acquisition and synchronization, life-log representation and mapping, life-log monitoring and big data storage processes [10].

The working of MM platform from application point of view is divided into three execution modules related to the education, recommendations and Q&A selection. The execution modules support for the real time adaptation of education, recommendation, and selection of the Q&A.

1) Adaptive Education

The education related to healthy behavior is an important aspect and necessity for the change in the behavior. There are two ways to provide education: 1) Generalized education, 2) Adaptive education. Initially system is not able to understand the condition of the customer. The condition of the customer depends on the life-log data gathered from multiple sensors available in smart watch, smart phone, and Kinect depth camera [10]. The life-log building is a time consuming process and to understand the activities status of the consumer at least one week life-log data is required. The challenge of cold start based life-log data-less condition is managed through initial questionnaire survey to get the knowledge of user habits and behavior.

2) Adaptive Recommendations

The adaptive just-in-time recommendations related to unhealthy behavior is an important aspect and necessity for the adaptation in the behavior. The change in behavior is an ongoing process in which the just-in-time related recommendations play a vital role. The general recommendations has influence on the human behavior for few days but the adaptive recommendations keep the customer interest until it matches with the condition and situation of the customer with proper track back facility. The recommendation generation is based on the user lifelog, preferences, environmental context, calories consumption, calories burn, and disease status [9]. The driving information for the recommendation generation is obtained from the expert in the form of rules which consider the multiple condition of the contributing factors to build a situation for the recommendation.

3) Adaptive Q&A Selection

An appealing and challenging aspect of behavior management applications is to gain interest of customers. The redundancy and irrelevancy of information to the customers are the most important issues. To cope the challenge, framework requires to understand the situation and consider the personalization of the customer. Questionnaire is an important way to get the personal details and preferences [12]. The issue is to ask same questions every time for the information extraction. So it is very necessary in behavior adaptation, that the questionnaires must be adaptive with respect to the customer condition. It means if some behavior is as per the recommended status no need to ask or inquire about that behavior.

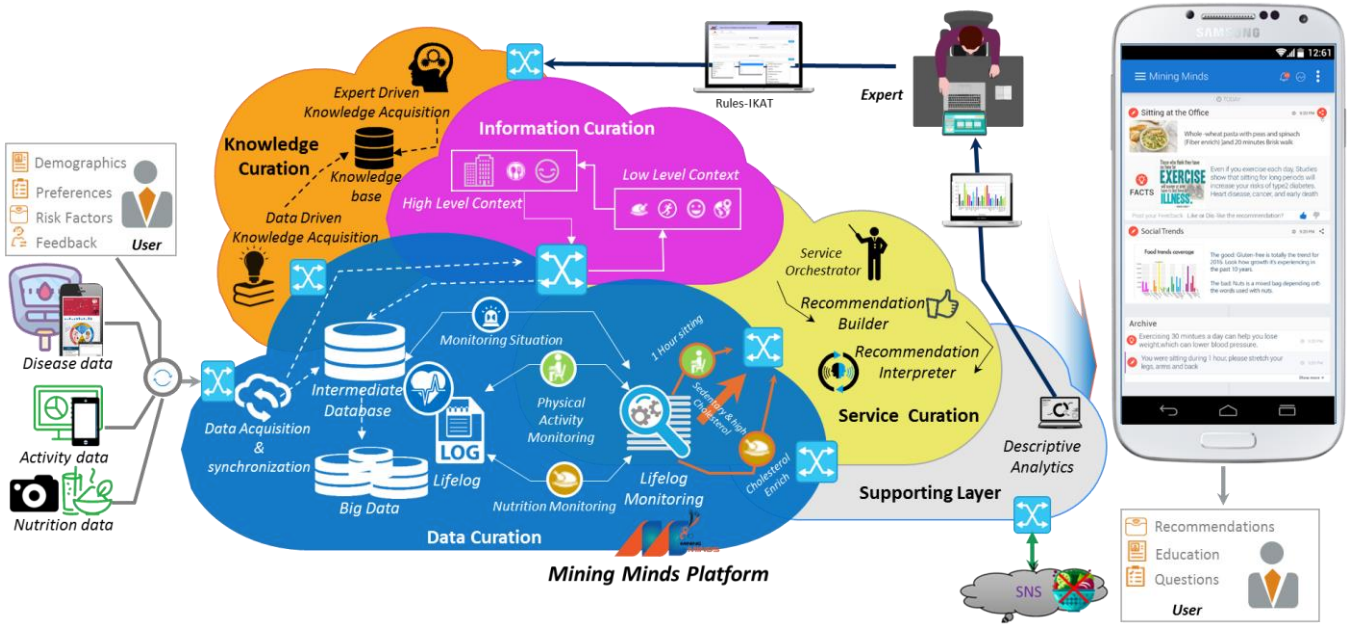

Figure 2 Methodology for the behavior change [15]

C. Mapping Behavior change Theory to Wellness Management Platform

We consider the lifestyle factors related to physical activity, BMI, dietary pattern, smoking and alcohol addiction for the analysis of healthy behavior status. As, behavior change theories, multiple stages are related to situation of the user. After analysis of the status we mapped the user status with TTM stages for providing the respective level of support in term of education, recommendation and observation as discussed in Table IV. The stages mapping is critically important to retain the interest of the users towards personalized wellness services.

TABLE IV
MAPPING OF TTM STAGES WITH PROPOSED STEPS

Sr. #	Proposed Steps	TTM Stages	Definition
1	Registration	Pre-contemplation	Gather information of behavior through questionnaire and understand user physiological information
2	Education	Contemplation	Identify the abnormal areas from responses of the user as well as lifelog to generate appropriate education
3	Recommendation	Preparation & Action	Support just-in-time intervention for adapting the healthy lifestyle habits at real time
4	Evaluation	Maintenance	Observe the change in behavior without providing any education or recommendation for evaluation.

III. EVALUATION OF PROPOSED METHODOLOGY

We have evaluated the proposed methodology through recruiting the persons with chronic disease diabetes. It is lifestyle based chronic disease and persons with diabetes require knowledge and support to perform healthy behavior along with monitoring of the lifestyle behavior.

These recruited person are managed into three stages to provide education, recommendation and evaluation. The 1st stage is about the education, in which after registration, person is provided daily education regarding the healthy lifestyle and the disease. This stage is four week long. In 2nd stage, user are provided recommendation either event based or time based. Time based recommendations are regarding the breakfast, lunch and dinner, while event based are depending on the abnormal situation of a behavior. The duration of this stage is nearly 6 weeks. The last stage is about evaluation of the change in behavior to have a healthy lifestyle. We have 106 persons with age greater than 45 years and both of the gender. No one has any physical disability and are expert enough to use smart phone. The all communication for intervention is taking place through the smart phone and we get the feedback through the questionnaire available on the app.

The education placed an impact of nearly 67% on the change in behavior towards healthy lifestyle where just-in-time recommendation has an impact of about 89% on adapting the lifestyle to adopt healthy behaviors as shown in Fig. 3. The last stage, where only evaluation is performed without intervention, we observed that 79% users retain the adopted healthy behavior without any support whereas about 20% users show unhealthy practices as shown in Fig. 3.

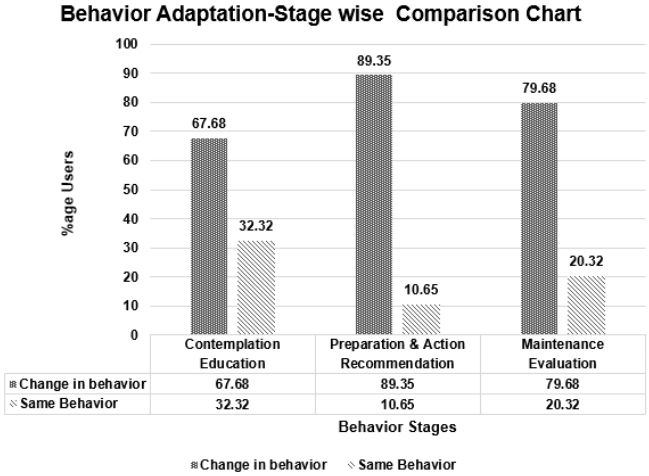

Figure 3 Comparison of behavior adaptation stage wise.

IV. CONCLUSION

We have utilized the life-log as well as lifestyle questionnaire's responses obtained using the MM wellness platform. The platform is utilized to communicate recommendations and education at different level with respect to the user behavior stage. The result shows that education has support many users at initial stage to understand the unhealthy behavior and personalized recommendations boost the users to adapt healthy lifestyle behavior. The evaluation shows that nearly 78% users have acquired more than 87% healthy lifestyle behaviors while the 16% users have acquired more than 68% healthy lifestyle and about 5% users need more support and personalized recommendations. In future, we want to evaluate our result more on the basis of the age groups instead of consider a single age group and consider other diseases like CVD or hypertension to confirm our methodology.

ACKNOWLEDGMENT

This research was supported by the Ministry of Science and ICT (MSIT), Korea, under the Information Technology Research Center (ITRC) support programme (IITP-2017-0-01629) supervised by the Institute of

Information & Communications Technology Planning & Evaluation (IITP), this work was supported by an IITP grant funded by the Korean government (MSIT) (no.2017-0-00655) and this research work was supported by Zayed University Research Incentives Fund (R18052).

REFERENCES

[1] C. M. News, "The future of health care is in the data,"http://www.cmu.edu/news/stories/archives/2015/march/the-future-ofhealth-care-is-in-the-data.html, 2015.

[2] Healy, G. N., Dunstan, D. W., Salmon, J., Cerin, E., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2008). Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes care*, *31*(4), 661-666.

[3] Katz, D. L., & Meller, S. (2014). Can we say what diet is best for health?. *Annual review of public health*, *35*, 83-103.

[4] Kvaavik, E., Batty, G. D., Ursin, G., Huxley, R., & Gale, C. R. (2010). Influence of individual and combined health behaviors on total and cause-specific mortality in men and women: the United Kingdom health and lifestyle survey. *Archives of internal medicine*, *170*(8), 711-718.

[5] Willett, W. C., Koplan, J. P., Nugent, R., Dusenbury, C., Puska, P., & Gaziano, T. A. (2006). Prevention of chronic disease by means of diet and lifestyle changes. In *Disease Control Priorities in Developing Countries. 2nd edition*. The International Bank for Reconstruction and Development/The World Bank.

[6] Mahmood Ahmad, Muhammad Bilal Amin, Shujaat Hussain, Byeong Ho Kang,Taechoong Cheong, and Sungyoung Lee. 2016. Health Fog: A novel frameworkfor health and wellness applications. The Journal of Supercomputing 72, 10 (2016),3677–3695.

[7] Kwasnicka, D., Dombrowski, S. U., White, M., & Sniehotta, F. (2016). Theoretical explanations for maintenance of behaviour change: a systematic review of behaviour theories. *Health psychology review*, *10*(3), 277-296.

[8] White, J., Greene, G., Kivimaki, M., & Batty, G. D. (2018). Association between changes in lifestyle and all-cause mortality: the Health and Lifestyle Survey. *J Epidemiol Community Health*, *72*(8), 711-714.

[9] Afzal, M., Ali, S. I., Ali, R., Hussain, M., Ali, T., Khan, W. A., ... & Lee, S. (2018). Personalization of wellness recommendations using contextual interpretation. *Expert Systems with Applications*, *96*, 506-521.

[10] Amin, M., Banos, O., Khan, W., Muhammad Bilal, H., Gong, J., Bui, D. M., ... & Chung, T. (2016). On curating multimodal sensory data for health and wellness platforms. *Sensors*, *16*(7), 980.

[11] Garcia, R., & Benavidez, D. (2016). Transtheoretical Model Key Constructs Applied to the Intervention & Treatment of Weight Cycling & Yoyo Dieting Cognitive-Affective Bases of Health for Weight Management. *Int J Complement Alt Med*, *3*(3), 00071.

[12] Hussain, J., Hassan, A. U., Bilal, H. S. M., Ali, R., Afzal, M., Hussain, S., ... & Lee, S. (2018). Model-based adaptive user interface based on context and user experience evaluation. *Journal on Multimodal User Interfaces*, *12*(1), 1-16.

[13] Bilal, H. S. M., & Lee, S. (2017, October). Integration of transtheoretical model with wellness big data for healthy behavior assessment to adoption. In *2017 International Conference on Information and Communication Technology Convergence (ICTC)* (pp. 753-756). IEEE.

[14] Ali, T., Hussain, M., Afzal, M., Khan, W. A., Hur, T., Amin, M. B., ... & Lee, S. (2018). Clinically harmonized wellness concepts model for health and wellness services. IEEE Access, 6, 26660-26674.

[15] Bilal, H. S. M., & Lee, S. (2019, June). Right Intervention at Right Time to Right Person for Healthy Behavior Adaptation. In Proceedings of the 17th Annual International Conference on Mobile Systems, Applications, and Services (pp. 618-619). ACM.

Hafiz Syed Muhammad Bilal received his MS. degree in Information Technology from National University of Sciences and Technology, Islamabad, Pakistan in 2008. He worked as Assistant Professor at the Department of Computer Engineering, National University of Sciences and Technology, Pakistan. Currently, he is a Ph.D. student in UC Lab, Kyung Hee University, South Korea. His research interest includes behavior modeling, Healthcare and wellness management.

Asad Masood Khattak received his Ph.D. degree in Computer Engineering from Kyung Hee University, South Korea in 2012. He worked as Post-Doctoral Fellow at the Department of Computer Engineering, Kyung Hee University, South Korea and later joined the same department as Assistant Professor. In August 2014, he moved to Zayed University, UAE as Assistant Professor and was promoted to Associate Professor Position in July 2017. His current research focus is User Profiling, Ontology, Knowledge Management, and Context-aware Computing. He is currently leading two research projects and participating in three additional research projects. He has authored/coauthored more than 90 journal and conference articles in highly reputed venues.

Sungyoung Lee received the B.S. degree from Korea University, Seoul, South Korea, and the M.S. and Ph.D. degrees in computer science from the Illinois Institute of Technology, Chicago, IL, USA, in 1987 and 1991, respectively. He was an Assistant Professor with the Department of Computer Science, Governors State University, University Park, IL, USA, from 1992 to 1993. He has been a Professor with the Department of Computer Engineering, Kyung Hee University, South Korea, since 1993, where he has been the Director of the Neo Medical ubiquitous-Life Care Information Technology Research Center since 2006. He is currently the Founding Director of the Ubiquitous Computing Lab-oratory. His current research interests include ubiquitous computing and applications, wireless ad hoc and sensor networks, context-aware middle-ware, sensor operating systems, real-time systems and embedded systems, and activity and emotion recognition.